

BACKGROUND OF THE INVENTION

1. Field of the invention

This invention relates in general to video processing and in particular to a method and device for providing instant replay of video.

5

2. Description of the prior art

Instant replay permits a viewer to rewatch a portion of a video program for closer study, e.g. to rewatch a play in a sporting event. In U.S. Patent No. 5,371,551 an instant replay device is provided with a circular memory for recording video for later replay. Each frame of video is simply stored in a memory at an address equally spaced from the next frame, which means the memory in U.S. Patent No. 5,371,551 does not take advantage of current MPEG standards which permit variable length encoding of frames.

15

In addition current MPEG-2 decoders receive the video information in the form of a compressed bit stream. The order of the pictures (e.g. I,P,B,B) in the compressed bit stream is different than the decompressed order in which the video is displayed (e.g. I,B,B,P). This reordering is necessary to ensure that all of the anchor frames needed to reconstruct the current frame have been received by the decoder first. The MPEG syntax does not contain any element which correlates the order of the pictures in the compressed domain to the order of the pictures in

20

the decompressed domain.

For operation of instant replay some correlation would be advantageous because a user typically views the decompressed video and then selects a portion of this video to be instantly
5 replayed. This portion is then retrieved from memory and redisplayed. Since there is no correlation in MPEG between the decompressed video that is displayed and the compressed video, the storage device must store the decompressed video in order to begin replaying the video at the appropriate point in the video
10 stream. This requires large costly memories.

SUMMARY OF THE INVENTION

Accordingly it is an object of this invention to
15 provide instant replay for an MPEG encoded video stream, including video streams received via live terrestrial transmission, by storing the data in the compressed domain and providing non-MPEG frame tags for correlation to the decompressed domain.

20 It is another object of the invention to provide instant replay of video without adding substantial cost to the video decoder.

It is a further object of the invention to provide instant replay which is not limited to any one profile or level
25 of MPEG.

It is yet another object of the invention to provide

instant replay in a system which optimizes the use of the memory by utilizing the benefits of variable length encoding.

Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification.

The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the others, and the apparatus embodying features of construction, combinations of elements and arrangement of parts which are adapted to effect such steps, all as exemplified in the following detailed disclosure, and the scope of the invention will be indicated in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the invention reference is had to the following drawings:

Fig. 1 shows an example of the components of prior art video decoders;

Fig. 2 shows a block diagram of the FLD, VLD, rate buffer, replay memory, rate buffer control and replay controller in accordance with the invention;

Fig. 3A shows the components of the video stream in the decompressed display order;

Fig. 3B shows the components of the video stream in the compressed order;

Fig. 4 shows a more detailed view of the replay memory and replay controller; and

Fig. 5 shows the elements of a video decoder in accordance with the invention.

5

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows the components of present MPEG video decoders. The fixed length decoder (FLD) 10 decodes the syntactical information in the headers of the MPEG video stream from the PES layer to the Picture layer and provides this information to many of the remaining decoder elements. The FLD 10 also indicates to the rate buffer 12 the beginning of the compressed video sequences, pictures and/or GOPs etc. The data arrives at the rate buffer 12 at a slower data rate than the data rate required for decoding and viewing. By buffering the data in the rate buffer 12 the data can be synchronized to the audio stream and to time stamps used for buffer management and provided to the display at a real time data rate.

The variable length decoder (VLD) 14 transcodes the variable length code words of the compressed video data into run length codewords. The run length decoder (RLD) 16 transcodes run length code words into quantized coefficient values. The inverse quantizer (IQ) 18 maps quantized coefficient values to non-quantized coefficient values e.g. discrete cosine transform (DCT) coefficient values. The inverse discrete cosine transformer

(IDCT) 20 performs an inverse transform operation on the DCT coefficients to produce pixel value differences. The motion compensation reconstruction subsystem 22 takes the pixel value differences and uses motion vectors and the frames (e.g. I and P frames) stored in the anchor frame stores 24 and 26 to build the decompressed video frames. The I frames are stored in anchor frame store 24 and then displayed. As the I frame is displayed, the following P frame is reconstructed and stored in the frame store 26 and the B frames are decoded by the reconstruction subsystem 22. The decompressed pixel values are displayed by the display processor 28.

As stated above the rate buffer 12 stores the compressed video pictures. The display processor 28 displays the decompressed video pictures. The order in which the decompressed pictures are displayed is not the same as the order in which the compressed pictures are stored. So, for example, if the compressed video stream is $I_1, P_4, B_2, B_3, \dots$, the display order may be $I_1, B_2, B_3, P_4, \dots$. This reordering poses a problem for implementing instant replay. The problem is as follows: assume instant replay of the last two displayed pictures is requested while the P_4 picture is being displayed. In the decompressed domain the B_3 and P_4 picture would be redisplayed, since they are the last two pictures. In the compressed domain the B_2 and B_3 pictures would be redisplayed, as these are the last two pictures stored in the rate buffer 12. Since, the user is watching the decompressed video it is this video (B_3, P_4) that the user would

like replayed, but the rate buffer 12 does not hold the pictures in this order (B_2 , B_3). If a request for instant replay is received by the video decoder it must determine which picture was last displayed and retrieve and redisplay the last X number of pictures depending on the length of instant replay requested. This means that if the P_4 frame is being displayed (i.e. the fourth frame of the decompressed video information), and only the compressed frames are stored, the replay process must correlate the decompressed displayed P_4 frame to the position in the rate buffer 12 of the compressed P_4 frame (i.e. the second frame of the compressed video information). (This example disregards the need for anchor frames as explained below).

In addition once the frames are in the decompressed domain the frame type information, whether a P, B or I frame is being displayed, is lost. The instant replay decoding process, however, needs this "frame type" information as it must start the decoding process with an I frame in order to decode the frames in accordance with MPEG. Therefore, the nearest I frame to the first instant replay frame to be decoded must be found in the rate buffer 12 which means frame type information (I,P,B) must also be retrieved from the compressed domain.

Figure 2 shows a video decoder which solves this problem. The video picture information is received from the FLD 10 in the rate buffer write control 32 of the rate buffer control 30, and in the replay write control and tag insertion 42 of the replay memory control 40. The rate buffer write control 32

writes the video picture information and the necessary header information which dictates the type of picture (I,P,B) into the rate buffer 12 and provides pointer values to the rate buffer pointer store 34 which pointer values indicate the starting address of the pictures. There is no requirement that the pointer values must keep track of "pictures" as in an alternative embodiment the pointer values could indicate the beginning of sequences, groups of pictures (GOPs), I frames etc. The rate buffer read control 36 receives the pointer values from the rate buffer pointer store 34 and reads the picture information from the rate buffer 12.

The invention provides the addition of marker tags to the video picture information. The replay write control and tag insertion 42 adds tags to each picture, each tag having a unique counter value (e.g. 0 to 1799). The range 0-1799 (1800 pictures) allows for up to 60 seconds of storage of 30Hz material (1800 frames of 30 frames/sec material = 60 seconds of replay video). The invention is not limited to counter values (0-1799) as other types of tags could be used.

During decode the FLD 10 detects the start of the pictures (the beginning point of the video information for each picture), flagging each start location in the bit stream. The marker tags are placed into the partially decoded bitstream by the replay write control and tag insertion 42, creating a modified bit stream which is written to both the rate buffer 12 and the replay memory 44. The marker tags are stored in the replay pointer

store and mapper 48 and mapped to the pointers. The pointers indicate the addresses where the start of the pictures are stored. Fig. 4 shows one example of the replay memory 44 and its control features.

5 The rate buffer read control 36 receives the pictures along with the marker tags and provides them to the VLD 14. As seen in Fig. 5 the tag is carried throughout the decoder to the display processor 28.

10 If the display processor 28 receives an instant replay request it provides the marker tag of the presently viewed frame to the replay read control 46. The replay read control 46 provides the marker tag to the replay pointer store and mapper 48. The pointer store and mapper 48 maps the marker tag to the address in the replay memory 44 of the location of the video
15 frame having the corresponding marker tag. The replay read control 46 then rolls back its address to the address of the start-of-replay video frame occurring approximately 1800 frames before the marked frame. If the start-of-replay video frame is not an I frame the nearest I frame in the bit stream is used and
20 this frame becomes the new start-of-replay video frame. The method in which this I frame is found is explained below but involves the replay read control 46 accessing the replay memory location of the start-of-replay frame and checking the header information of this frame to see if it is an I anchor frame. If
25 the start-of-replay frame is not an anchor frame an earlier pointer value is requested from the replay pointer store and

mapper 48. For example, in one embodiment the address roll back can be determined with reference to stored marker tags. The pointer store and mapper 48 stores the information indicating the nearest I frame and provides the address of the nearest I frame as the start-of-replay video to the replay read control 46. In other words, the marker tag itself for each frame references the nearest I frame. The replay video is then provided to the VLD 14 for decoding. One of the benefits of this invention is that the replay memory 44 stores the compressed video which means the replay memory 44 is relatively small as compared to storage required for the decompressed video. In addition, because the marker tags reference the address of the start of pictures there is no need to store the pictures equally spaced from one another to maintain easy referencing. Instead, each frame is stored using as little memory as required for that particular variable length encoded frame, and direct correlation between the compressed and decompressed domains is still maintained.

The following is a description for detecting the first I frame for instant replay. Since the video data is stored in the compressed order, all anchor frames needed to decode the current frame are stored in memory before the current frame. The anchor frame searching schemes described below can be performed by the replay pointer store and mapper 48 in conjunction with the replay read control 46.

25

If the start-of-replay frame from the instant replay memory is an

I frame

The replay memory controller 40 reads this I frame into the video decoder. The replay read control 46 rolls its address forward to the next P frame. If reference is made to Fig. 3B, this means the I_0 frame is read and then the P_3 frame. The P_3 frame is decoded from the I_0 frame, then all frames after the P_3 frame are decoded. (See example 1 below).

If the start-of-replay frame from the instant replay memory is a P frame

The replay memory controller 40 looks for the preceding I frame in memory. This I frame (e.g. I_0 in Fig. 3b) is used to decode the start-of-replay P frame (e.g. P_3). Then, the memory controller 40 reads forward in memory to the anchor frame following the start-of-replay P frame. If this anchor frame is also a P frame (e.g. P_6), then the preceding I frame is used to decode this P frame. Both the start-of-replay P frame and following P frame are used to decode the B frames following start-of-replay (e.g. I_0 is used to recover P_3 and P_6 ; P_3 and P_6 are used to recover B_4 , and B_5). See example 2 below. If the anchor frame following the start-of-replay P frame is an I frame, then the start-of-replay P frame and that I frame are used to decode the B frame(s) following the start-of-replay P frame (see example 3 below).

25

If the start-of-replay frame from the instant replay memory is a

B frame

The replay controller 40 searches back through the instant replay memory 44 until a P frame (here labeled P_1 for clarity) is found. P_1 is needed to reconstruct the start-of-replay B frame, and is retrieved from the instant replay memory. At this point the replay controller 40 searches for an I frame. If the P_1 frame is immediately preceded by an I frame, then it searches no further: the I frame and the P_1 frame thus found are used to reconstruct the start-of-replay B frame. If the P_1 frame is not immediately preceded by an I frame, then the preceding P frame, along with the P_1 frame, are used to reconstruct the start-of-replay B frame. However, both P frames must themselves be reconstructed from the preceding I frame. Thus, the replay controller 40 must find the preceding I frame (skipping over any further P frames it may encounter). Once the I frame is found, it is used to decode the two P frames, which in turn, are used to decode the start-of-replay B frame. (See examples 4 and 5 for clarification).

EXAMPLES

Example 1:

Assume the start-of-replay frame is found to be I_9 in Figure 3b. I_9 is loaded into the video decoder, then P_{12} is decoded, then B_{10} and B_{11} (note: it skips B_7 and B_8 since they won't be in the GOP started by I_9). After B_{10} and B_{11} , it decodes as normal.

Example 2:

Suppose the start-of-replay frame is P_3 in Figure 3b. First the replay read control 46 reads back through the replay memory to find the preceding I frame (e.g. I_0). Then the replay read control 46 searches forward in memory to the anchor frame following P_3 . In this case, the next anchor frame will be P_6 . Then the decoder uses I_0 to decode both P_3 and P_6 . Then P_3 and P_6 are used to decode B_4 and B_5 . After B_4 and B_5 , normal decoding proceeds.

10

Example 3:

Suppose the start-of-replay frame is found to be P_6 in Figure 3b. The replay read control 46 first looks for the preceding I frame (in this case, I_0). Then it looks for the anchor frame following P_6 , (in this case, I_9). The video decoder uses I_0 to decode P_6 , then uses P_6 and I_9 to decode B_7 and B_8 . Normal decoding proceeds after B_8 .

15

Example 4:

Assume the start-of-replay frame is found to be B_1 in Figure 3b. The preceding P frame (in this case P_3) is then found. Then the replay memory controller searches for the previous I frame (in this case I_0). The video decoder uses I_0 to decode P_3 . The video decoder uses I_0 and P_3 to decode B_1 . The video decoder decodes normally thereafter.

20

25

Example 5:

Assume the start-of-replay is found to be B_5 in Figure 3b. The replay memory controller first looks back earlier in time to find the first P frame (in this case, P_6). Then it searches further for an I frame. At one point, it comes across P_3 . This indicates that the B frame in question will have to be decoded from two P frames. Therefore, P_3 is noted. Looking further back into memory, the replay memory controller comes across I_0 . The decoder uses I_0 to decode P_3 and P_6 . The decoder uses P_3 and P_6 to decode B_5 . The decoder proceeds with normal decoding after B_5 .

In an alternative embodiment of the invention the replay memory 44 and the rate buffer memory 12 can be combined. The pointer address of each frame can be used as the marker tag and passed along the decoding chain. The pointer address can then be used to locate in the combined memory the present compressed video frame being viewed. Such a scheme would eliminate the duplication of the control systems 30 and 40 and the memories 12 and 44.

It should be noted that the invention has been described with reference to storing the slice layer of the MPEG stream, but it can also be implemented in other layers such as the transport layer. In addition although the invention was described with respect to MPEG1 and MPEG2, it can be implemented in any MPEG video syntax that uses compressed and decompressed

video signals in the decoder.

A further note, if the video stream includes SMPTE time codes then these can be used as the marker tags.

It will thus be seen that the objects set forth above,
5 among those made apparent from the preceding description, are
efficiently attained and, since certain changes may be made in
carrying out the above method and in the construction set forth
without departing from the spirit and scope of the invention, it
is intended that all matter contained in the above description
10 and shown in the accompanying drawings shall be interpreted as
illustrative and not in a limiting sense.

11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2198
2199
2200
2201
2202
2203
2204
2205
2206
2207
2208
2209
2210
2211